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THE KEI ISLANDS MONITOR LIZARD (SQUAMATA: VARANIDAE: *Varanus*: *Euprepiosaurus*) AS A DISTINCT MORPHOLOGICAL, TAXONOMIC, AND CONSERVATION UNIT

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We describe a new species of the *Varanus indicus* group (subgenus *Euprepiosaurus*) from the Kei Islands, Indonesia, which differs from its close relative *V. indicus* by a light tongue, a conspicuous color pattern composed of distinct yellowish ocelli on a blackish ground color and by some scalation characters. From its more distantly related, but morphologically similar relative *V. finschi* it differs by its midbody scale count and by some peculiarities of its scale microstructure. The new taxon, endemic to the Kei Islands, is also discussed in the light of conservation problems for many Indonesian island endemics.

Keywords: *Varanus*; new species; Kei Islands; Maluku Province; Indonesia; conservation.

INTRODUCTION

The Mangrove Monitor Lizard, *Varanus indicus* (Daudin, 1803), type species of the subgenus *Euprepiosaurus* Fitzinger, 1843, has been dismantled as a collective species and found to be composed of meanwhile no less than 15 different, partly allopatric taxa which are commonly considered as species. According to the classical monograph by Mertens (1942), this species group consisted of one single species only, with two additional subspecies. Two decades later, the same author (Mertens, 1963) listed in his checklist in the famous series "Das Tierreich" only one additional species. When Böhme (1997) actualized the taxonomy of the genus, the number of species in the *V. indicus* group was augmented only by one more species (plus one subspecies). In a following checklist (Böhme, 2003), five additional species were added, one of them (*V. finchi*) by upgrading it from its former subspecific level. An account on the taxonomic history of the *Euprepiosaurus* species was provided by Ziegler et al. (2007). The checklist by Böhme (2003) was updated by Koch et al. (2010) who added again four additional species that had been described in the mean-time, and removed one (*V. spinulosus*) from the *indicus* group, since it turned out not even to belong to the subgenus *Euprepiosaurus* (see Böhme and Ziegler, 2007, Bucklitsch et al., 2016). After that update, two further new species of this group have been described (Weijola, 2016, 2017), one of them (*V. douarrha*) raised from synonymy, the other one formerly unknown to science (*V. semotus*), but morphologically nearly indistinguishable from *V. doreanus*. This will certainly not be the definite number of species in this group as shown by Weijola et al. (2019) who revealed in a new, very recent molecular study even a much higher level of undescribed cryptic species diversity.

Due to the complicated taxonomic situation in this species group, the identity of the true *Varanus indicus* in the strict sense, described as *Tupinambis indicus* Daudin, 1802 (type locality Ambon, Moluccas, but type lost) was redefined by designation of a neotype by Philipp et al. (1999). This designation was challenged by Weijola (2015) who suggested to replace this neotype by another one from a different type locality. This proposal was countered by Böhme et al. (2016) to avoid nomenclatural confusion.

The two easternmost archipelagos of the Indonesian Maluku Province are the Kei and the Aru Islands, the for-

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mer also often spelled as Kai. They harbour two populations of Mangrove monitor lizards which differ consistently from each other in their color pattern. The first author who noted this difference was Doria (1874) who listed four individuals from these two island groups and stated that those from Aru had very small yellow spots on their dorsum, each of the size of a single scale only. The Kei specimens, in contrast, would have extended flecks of eight to ten scales width, tending to form ocelli. Also six Kei specimens studied by Roux (1910) had dorsal flecks extending over several scales and forming rings, especially in younger specimens. Roux (1910) emphasized that none of these specimens showed the very small spots as they are typical for the Aru population. This striking difference in color pattern of the Kei specimens, together with their light, unpigmented tongues, reminded us strongly of the phenotype of *V. finschi* from New Britain, Bismarck Archipelago, so that we first suspected possible taxonomic conspecifity (Philipp et al., 2004, see also Weijola et al., 2016). Later, however, also for biogeographical reasons, we called this population informally the "Kei *finschi*" form or "*V.* cf. *finschi*" (Bucklitsch et al., 2012, 2016) since in the meantime it had become clear to us that this informal assignment meant only phenetic similarity due to convergent evolution and not conspecifity!

In the recent past, two molecular genetic studies including also samples from the Kei Islands were performed by Arida (2017) and by Weijola (2017), and voucher specimens from both the Kei and the Aru islands were found to be nested within a clade assigned to *Varanus indicus*. This is, however, not mirrored by their morphological diversity. In this paper we discuss the status of the Kei Islands monitor lizard and propose a new island taxon based on morphological characters.

MATERIAL AND METHODS

Specimens were morphologically analyzed by measurements and scale counts according to the methods employed and described by Brandenburg (1983), Böhme et al. (1994), and Ziegler et al. (2007). Also, Brandenburg's abbreviations for the single characters are used here again for a better comparability.

Data on scale ultrastructure were taken from the study by Bucklitsch et al. (2016) based on ZFMK's SEM facility (Hitachi scanning electron microscope), where the methodology is described in detail. The preparation of a fixed, secondarily everted hemipenis done by Thomas Ziegler is likewise methodologically described by Ziegler and Böhme (1997).

Institutional abbreviations. BMNH (= NHM), Natural History Museum, London, United Kingdom; MZB, Museum Zoologicum Bogoriense, Bogor, Indonesia; NMB, Naturhistorisches Museum Basel, Basel, Switzerland; NMW, Naturhistorisches Museum Wien, Vienna, Austria; SMF, Senckenberg Forschungsinstitut und Naturmuseum, Frankfurt am Main, Germany; WAM, West Australian Museum, Perth, Australia; ZFMK, Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany; ZMA, Zoologisch Museum, Universiteit van Amsterdam, The Netherlands (meanwhile transferred to the Dutch National Museum "Naturalis," Leiden); ZMUC, Zoologisk Museum, University of Copenhagen, Denmark.

RESULTS AND DISCUSSION

A morphological comparison of the Kei Islands monitor lizards with specimens from neighbouring areas corroborated marked, constant differences in color pattern as described already by earlier researchers (Doria, 1874, Roux, 1910, Phillip et al., 2004), and briefly mentioned also by Karin et al. (2018). Our study, however, revealed moreover clear differences in several scalation characters, too (Bucklitsch et al. 2016, this paper: see below). Despite the low genetic distances in the genes studied so far (see Arida, 2017, Weijola et al., 2017, 2019, this paper: see below) the mangrove monitor lizard population from the Kei Archipelago forms a morphologically distinct unit that warrants recognition not only from a taxonomic but also from a conservational point of view.

Varanus (*Euprepiosaurus*) *colei* sp. nov.

Synonymy/Chresonymy. Mangrove monitor lizards from the Kei Islands have been cited in the literature under the following names, thus reflecting the taxonomic uncertainties:

Monitor chlorostigma — Doria (1874)
Monitor indicus — Peters et Doria (1878)
Varanus indicus — Boulenger (1885)
Varanus indicus — Roux (1910)
Varanus indicus — DeRooij (1915)
Varanus indicus — Sprackland (1992)
Varanus indicus — Böhme, Horn and Ziegler (1994)
Varanus indicus — Brandenburg (1983)
Varanus indicus — Böhme, Horn et Ziegler (1997)
Varanus finschi — Philipp, Ziegler et Böhme (2004)
Varanus finschi — Ziegler, Schmitz, Koch et Böhme (2007)
Varanus indicus — DeLisle (2009)

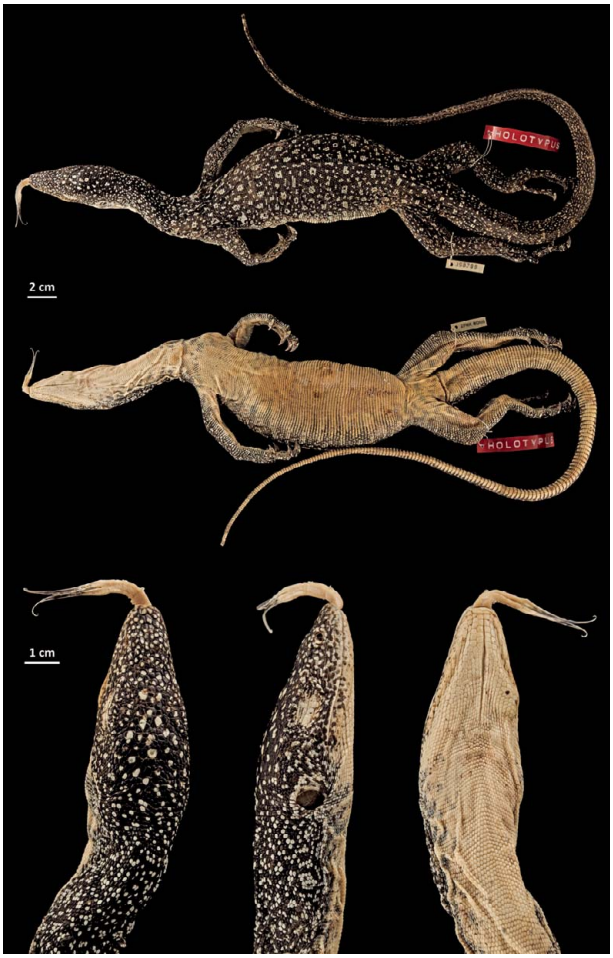

Fig. 1. *Varanus colei* sp. nov., holotype, MZB Lace. 14729 (ex-ZFMK 98799), Ohoitel near Tual, Kei Kecil Id., Kei Archipelago, Maluku Province, Indonesia. Photo by Morris Flecks.

Varanus cf. *finschi* — Bucklitsch, Böhme et Koch (2012)

Varanus finschi — Koch, Ziegler, Böhme, Arida et Auliya (2013)

Varanus cf. *finschi* — Bucklitsch, Böhme et Koch (2016)

Varanus indicus — Weijola (2017)

Varanus indicus — Weijola, Kraus, Vahtera, Lindqvist et Donnellan (2017)

Varanus cf. *finschi* — Arida (2017)

Varanus cf. *indicus* — Karin, Stubbs, Arifin, Bloch, Ramadhan, Iskandar, Arida, Reilly, Kusnadi et McGuire, 2018

Varanus indicus (s. str.) — Weijola, Vahtera, Lindqvist et Kraus (2019)

Holotype. MZB 14729 (ex-ZFMK 98799), male, Ohoitel near Tual, Kei Kecil Island, Kei Archipelago, Maluku Province, Indonesia, courtesy M. A. Cole, B. Soetanto, 2016 (Fig. 1).

Paratypes. ZMUC R 4267 – 4268 and 4270, ZFMK 84982 (ex-ZMUC R 4269), from Tual ("Toeal"), Kei Kecil Island, Kei Archipelago, Maluku Province, collected by Dr. Th. Mortensen, on 20 March 1922; and ZFMK 98800 – 801, ZFMK 101942 – 944, same data as holotype.

Further material. According to the intensive data collection on monitor lizards of the *V. indicus* group accumulated by Koch (personal communication), voucher material from the Kei Islands is present in six more natural history collections: BMNH, NMB, NMW, SMF, WAM, and ZMA. They will be evaluated within a larger framework in the course of a subsequent study (Koch, in preparation).

Diagnosis. A member of the *Varanus* (*Euprepiosaurus*) *indicus* species group which is characterized by a conspicuous dorsal pattern of ring-like yellow flecks on a dark dorsum (blackish in life), the scales adorned with yellow spots being slightly larger than the surrounding ones (Figs. 1 – 3, see also Fig. 29 in Karin et al., 2018). From the widely distributed *V. indicus*, which may still be a collective species where additional cryptic taxa may be hidden, it is distinguished by its light, dark spotted pinkish tongue (always dark bluish to black in *V. indicus*, see Böhme et al., 1994) and its having hemipenial paryphasmata on both sides of the sperm groove (Ziegler, unpublished) which are present on only one side of the sulcus in *V. indicus* (Böhme, 1991: Fig. 2C; Ziegler and Böhme, 1997: Fig. 31; Ziegler et al., 2007: Table 4).

From the phenetically most similar *V. finschi*, endemic to New Britain, Bismarck Archipelago, with which it shares a light tongue color, a light throat and a dorsal pattern of larger yellow, mostly ocellar spots, *V. colei* sp. nov., endemic to the Kei Archipelago, can be distinguished by considerably higher scale counts (e.g., midbody count: S value 139 – 155 vs. 106 – 137 in *V. indicus* s. str., Ziegler et al., 2007), and by the ultrastructure of its nuchal, dorsal, lateral and ventral scalation which shows markedly more and larger granules between neighboring scales. Moreover, *V. colei* sp. nov. is distinguished from *V. finschi* by having a posterior granulum at the nuchal scales only (not on neck and lateral scales), and more than one sensory pit in the neck scales (vs. only one in *V. finchi*) (Bucklitsch et al., 2012, 2016).

Description of holotype. Habitus slender. Total length (snout-vent length + tail length) 728 (288 + 440) mm. Head length 60.1, head width 25, head heigth 19.5 mm. Hind leg 123 mm. Scale counts (abbreviations according to Brandenburg, 1983): $P = 43$, $Q = 98$, $R = = 74$, $S = 148$, $T = 94$, $X = 43$, $XY = 161$, $c = 27/26$, $m =$

= 99, *n* = 35. Tail strongly compressed, a double-keeled crest beginning one headlength behind tail root.

Color pattern. Ground color blackish, with light, whitish-yellowish flecks on the upper side of head, neck, body, limbs and tail which tend to form ring-like ocelli with dark centers on dorsum and flanks. Underparts whitish-yellowish, with some dark oblique bands extending from the flanks but not reaching the midventral region. Throat whitish, some dark variegations on the anterior sternal region. The tail has some indistinct, light cross-banding.

Tongue light, with dark tips above and below which break up into some isolated dark flecks before merging into the light part of the tongue.

Hemipenis. The inverted left hemipenis of the male holotype was removed from the tail root and everted as described in Ziegler and Böhme (1997). According to Ziegler (unpublished) it proved to have paryphasma rows on both sides of the sulcal sperm groove which is an important difference to *V. indicus* (see above: Diagnosis).

Variation. The morphological description of the Kei Islands monitor population is so far based on the holotype and the 10 paratypes listed above (see Table 1). The five scalation characters selected (Brandenburg's characters *Q*, *S*, *X*, *XY*, and *m*) are those which proved already to be useful for the distinction between other members of the *V. indicus* group in our earlier papers on the taxonomy of *Euprepiosaurus* (Böhme et al., 1994, Ziegler et al., 2007). All values evaluated here are markedly higher than those given for *V. indicus* by Ziegler et al., (2007) and show no overlap (Table 2). The greater range of variation in earlier scale counts for *V. indicus*, e.g., in Böhme

Fig. 2. Living juvenile specimen of *Varanus colei* sp. nov. from Kei Besar Id., Kei Archipelago (WAM 109763). Photo by Paul Doughty.

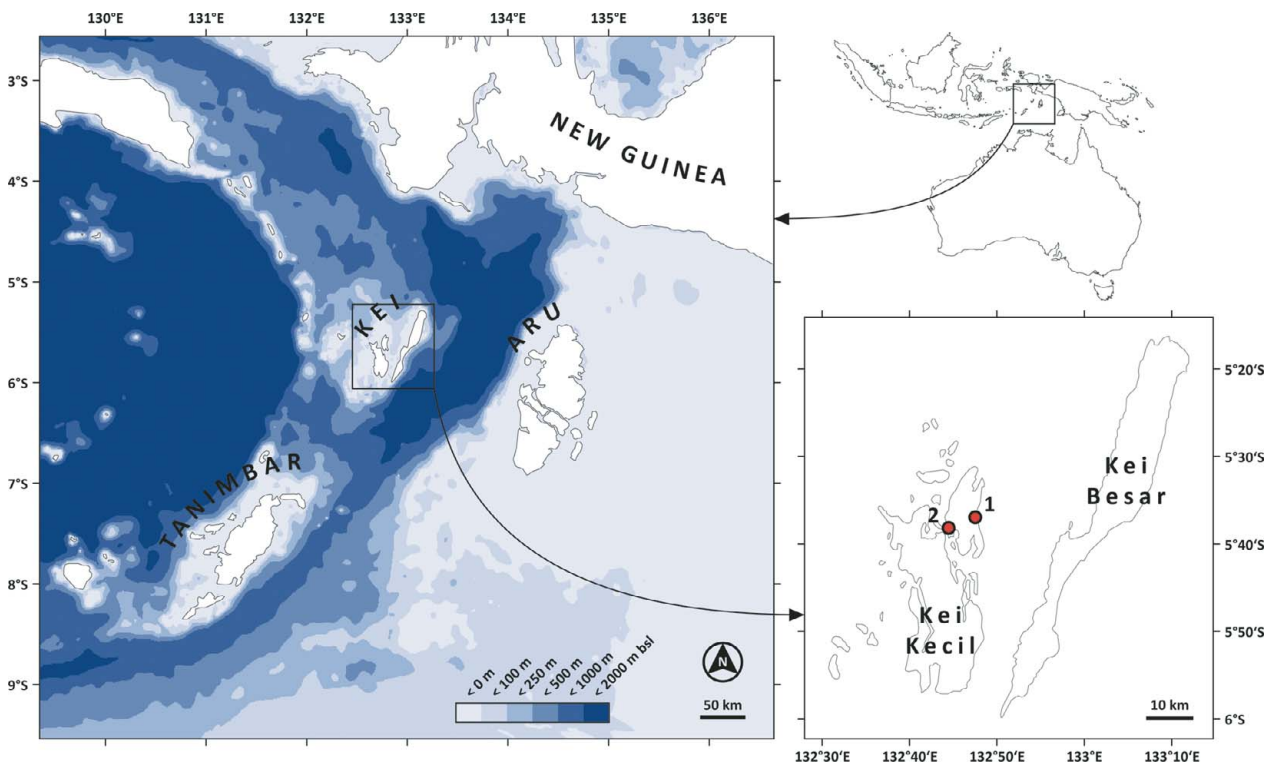

Fig. 3. Map of the Kei and Aru Archipelagos separated by the biogeographically important Lydekker's line. Red points show known localities for *Varanus colei* sp. nov. on Kei Kecil. Graphics by Morris Flecks.

TABLE 1. Scale Counts of the Type Series of *Varanus colei* sp. nov.

	Sex	*Q*	*S*	*X*	*XY*	*m*
MZB 14729 (ex-ZFMK 98799)	m	98	148	43	161	99
ZFMK 98800	f	98	155	41	162	107
ZFMK 98801	f	89	145	42	151	105
ZFMK 84982 (ex-ZMUC R 4269)	m	97	140	39	153	97
ZMUC R 4267	m	105	144	41	159	108
ZMUC R 4268	m	103	152	42	150	107
ZMUC R 4270	f	87	139	42	151	96
ZFMK 101941	m	97	145	42	158	107
ZFMK 101942	juv	96	148	40	153	103
ZFMK 101943	juv	92	146	41	151	95
ZFMK 101944	juv	98	144	42	150	101

Abbreviations: *Q*, Number of scales around tail root (first complete row of whorls behind anus); *S*, Scales around midbody; *X*, Number of oblique rows of dorsal scales, from a line connecting the upper margins of tympani with a line connecting the lateral ends of the gular fold; *XY*, *X* plus the number of oblique rows of dorsals from the line connecting the ends of the gular folds and the anterior base of hindlimb insertion; *m*, the number of scales around neck immediately in front of the gular fold.

TABLE 2. Range of Variation in Scale Counts of *Varanus indicus*, *V. finschi*, and *V. colei* sp. nov.

	Q	*S*	*XY*	*m*
Varanus indicus	58 – 85	106 – 137	105 – 140	70 – 94
Varanus finschi	95 – 110	158 – 196	169 – 199	86 – 145
Varanus colei sp. nov.	87 – 105	139 – 155	150 – 162	95 – 108

Data source: Ziegler et al. (2007) and this paper. Abbreviations as in Table 1.

et al. (1994), is due to the fact that some sibling species (e.g., *V. caerulivirens*, *V. cerambonensis*, *V. juxtindicus*) were not yet known and described at that time so that their scale counts may have been merged with those of what is today *V. indicus* s. str.

The color pattern of the paratypes is very similar to that of the holotype, with the characteristic dark-centered light ocelli on dorsum and flanks in the adults, a bit less expressed in the juveniles. The ground color is a bit lighter in the four specimens originating from ZMUC, obviously due to their longer preservation time since 1922. In ZFMK 98801, the dark ventral crossbands are more distinct than in the other paratypes.

The blurring of the dark tongue tips into the light main part of the tongue is more distinctly marked by isolated dark flecks, particularly in the ZMUC specimens. Photographs of voucher specimens from Kei Besar in the WAM kindly provided by Paul Doughty (Perth) show the same constant color pattern of yellow ocellar rings as on Kei Kecil (see Fig. 2). Further specimens of *V. colei* sp. nov. kept in other collections as mentioned above and to be published in a later study (Koch, in prep.) will certainly extend again the range of variation shown by the type series and can prove whether the differences in scale counts as compared with *V. indicus* will be corroborated or not.

The SEM pictures presented by Bucklitsch et al. (2016), documenting ultrastructural differences of *V. colei* sp. nov. as compared with *V. finschi* are based on paratype ZFMK 84982.

According to a phylogram published in Weijola et al. (2017), two specimens from Kei Besar (WAM 109763 – 764) are nested within a *V. indicus* clade that comprises also samples from Queensland and from the Aru Islands. Both specimens resemble our type series of *V. colei* sp. nov., although WAM 109763 has a bit smaller flecks without a black center on its back (Fig. 4). Likewise, the genetic distance (COI) between a sample of "*V.* cf. *indicus*" from Aru and one of "*V.* cf. *finschi*" from Kei Kecil is very low (0.3%: Arida, 2017).

The genetic distances between the true *V. indicus* and some other species of the complex, including the spectacular quince monitor lizard (*Varanus melinus* Böhme and Ziegler, 1989), are similarly low, so that a downgrading to subspecies rank could be taken into consideration. However, as it is also the case in, e.g., *V. melinus*, it is difficult to decide to which species the respective subtaxon should be assigned, because main diagnostic and constant characters of *V. indicus* (s. str.), e.g., the dark bluish tongue, or only unilateral paryphasmata on the hemipenis, are lacking in the taxa in question. It seems therefore advisable to treat also the new taxon *colei* as a species

Fig. 4. Free-ranging specimen of *Varanus indicus* on Enu Id., Aru Archipelago, Indonesia. Photo by Henk Strijbosch.

because it is a morphologically (both external and genital) and geographically definable unit and represents also a conservation unit of its own.

Distribution. *Varanus colei* sp. nov. is an endemic of the Kei Archipelago. On the main island Kei Besar (Great Kei) it has been reported from Elat and Warka (Roux, 1910; Karin et al., 2018), and on the second larger island Kei Kecil (Little Kei, with its NE part Kei Dulah) from Langgur (Roux 1910), the main place Tual and the village Ohoitel (this paper: Fig. 3). According to Karin et al. (2018) there was one sighting only of an adult specimen on Tam Island, but no voucher so far, while it was found to be absent from the westernmost outlier of the archipelago, viz. Kur Island, although locals had claimed it to be abundant on Kaimer Island just north of Kur.

Etymology. The new species is named after Michael Allan Cole, a US reptile enthusiast who established a "Wildlife Exploration Foundation" for nature education and for further discovery and preservation of wild and specifically new species. He supported also the discovery of the new monitor lizard taxon described here.

Biogeography. As can be seen in Fig. 3, isobath lines from 1000 to 2000 m b.s.l. separate the Kei Islands from the Aru Islands which are connected with New Guinea by a much shallower part of the Sahul Shelf than the former. This separation corresponds to an important biogeographical borderline which was first identified by mammalian distribution patterns (Lydekker, 1896) and is now known as Lydekker's line separating the Wallacean realm on its easternmost border from the New Guinean/Australian realm. This line (see Karin et al., 2018) argues for a longer isolation of the Kei Islands from New Guinea as compared to the Aru Islands and may explain the presence of tree monitors (*V. beccarii*) of the *Hapturosaurus* group of *Varanus* (Bucklitsch et al., 2012) on the latter islands which are absent from the former. Also, the presence of true *V. indicus* (sensu Böhme et al., 2016) on the Aru Islands (see Fig. 4) is explicable by this biogeographical pattern as well as its replacement on the Kei Islands by its close but nonetheless distinct relative *V. colei* sp. nov. Similarly, also the colubrid snakes of the genus *Stegonotus* have two different species on these two archipelagos which were formerly treated as synonyms: *S. aruensis* and *S. keyensis* (Kaiser et al., 2018).

The Kei Islands are housing several more endemic reptiles which are considered to be distinguished on ei-

Fig. 5. *Varanus* sp. (cf. *indicus*) from Tanimbar, easternmost Sunda Ids., Indonesia. Photo by Lutz Obelgönner.

ther the species or the subspecies level, e.g., the gekkonids *Lepidodactylus pantai*, *Nactus pelagicus undulatus*, the scincids *Cryptoblepharus keiensis*, *Sphenomorphus capitolythos*, *S. undulatus*, and *Tiliqua gigas keyensis*, the colubrid *Dendrophis keiensis* and others (Stubbs et al., 2017; Karin et al., 2018). Some of those listed now as full species were originally also first described as subspecies only. According to these authors, there are potentially more endemic species which are now still hidden under other species names. A next example in the geographical neighborhood could be found in the Tanimbar Archipelago situated southwest of the Kei Archipelago (Fig. 3). The mangrove monitor lizard population living there is also unusually patterned (Fig. 5) and suspected by Weijola et al. (2019) to be a cryptic candidate for an undescribed species. Biogeographically, this situation is paralleled by the skinks of the genus *Tiliqua*. *T. gigas keyensis* is the taxon endemic to the Kei Archipelago, while *T. scincoides chimaerea* is the respective endemic taxon of Tanimbar (Shea, 2000a, 2000b).

Conservation. As already stated by Philipp et al. (2004), "*V. finschi* from the Kai Islands" (i.e., our new species described here) "are regularly available in the pet trade." This means that there is some exploitation pressure on these island populations, too. Here, we agree with Shaney et al. (2017) that Indonesian monitor lizards in general and members of the *V. indicus* species complex in particular are unjustifiedly classified by CITES (2016) as "Least concern," since several distinct taxa, be they species or subspecies, can be hidden under the name of widely distributed species (for *Euprepiosaurus* see also Weijola et al., 2019) and thus undergo the risk of extinction before their existence as a discrete unit or taxon is recognized. The Kei Islands mangrove monitor lizard is one of these examples.

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ing specimens were also provided by Lutz Obelgönner (Bielefeld), and Henk Strijbosch (Nijmegen). Morris Flecks (ZFMK Bonn) took the photos of the holotype and prepared also the distribution map. Their help is also greatly appreciated.

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